

Effect Of Secondary Succession On The Changes In Soil Physicochemical Properties In The Cross River Rainforest, Nigeria

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Abstract

This study anchored on how secondary succession has affected the soil physico-chemical properties in the Cross River rainforest. The objective of the paper was to examine changes in surface and subsurface soil as influenced by secondary succession and the contributions made by the changes in relation to nutrients upgrade. The study area was the Oban group forest within the Southern part of Cross River State. Five succession phases were identified as follows forbs area (2-years old), young fallow (3-7 years) mature fallow (8-15 years) secondary climax (16-25 years) and primary climax (25 years and above). The soil samples were collected at the surface (0-15cm) and subsurface (15-30cm) levels. From the study findings, it was discovered that sand constituted more than 65% of the inorganic mineral fragment. Furthermore, the soils were classified as loamy-sand. However, there was a substantial increase in the levels of organic carbon and total nitrogen in the top soil across the various succession phases mostly in the mature fallow and primary climax. Hence, this increase in organic carbon and total nitrogen is attributed to the increase in the density of tree/shrubs, dense crown cover and the high amount of litter production through decomposition, thus, adding nutrient to the soil. Therefore, with a viable and functional luxuriant Cross River Rainforest, the livelihood sustainability of the forest community dwellers/inhabitants could be guaranteed upon the continuous availability of forest resources and services, vis-à-vis poverty alleviation.

Keywords: secondary succession, soil, physico-chemical properties, cross river rainforest and succession phases

INTRODUCTION

Secondary succession is the series of community changes which takes place on a previously colonized, but disturbed or damaged habitat. These changes might take place in areas which have been cleared of existing vegetation (such as after tree-felling in a woodland) and/or destructive events such as fires. Secondary succession is usually much quicker than primary succession because there is already an existing seed bank of suitable plants in the soil which aid re-growth of plants; the root systems of plants are undisturbed in the soil which enhances stumps and other plant parts from previously existing plants to rapidly regenerate. Also, the fertility and structure of the soil has also already been substantially modified by previous organisms to make it more suitable for growth and colonization.

Several studies have shown that secondary succession has great impact on soil fertility status (Diekmann *et al.* 2007; Sarmiento and Bottner, 2002; Moran *et.al* 2000; and Bisong, 1994). According to Van der Kamp (2009), the effects of secondary succession on soil are strongest in the A-horizon (0–10 cm), where an increase in carbon stock, N, and C/N ratio, and a decrease in bulk density and pH are observed. However, Maharning *et.al* (2009)

examined soil community changes during secondary succession to naturalized grassland, and discovered that in various successional stages approaching naturalized grasslands, interaction between plant species composition changes and soil ecology affect each other. Those changes in micro-arthropod communities are obscured; nematode trophic functional group (ecological guild) changes response to both plant and soil community changes.

Considering how succession impacts on soils in different *seres* otherwise called fallows, the trend of organic matter build – up has been assessed in parts of South-Western Nigeria and its resultant effects on soil properties (Aweto, 1981). Here he suffice that organic matter accumulation in fallow soil over time was largely confined to the top 10cm of the soil. He went further to state that the trends of nutrients build – up in fallow soils is similar to that of organic matter. Therefore, this assertion rest on the fact that organic matter exerts marked effects on the properties of fallow soils. Similarly, that the influence exerted by organic matter poses stronger influences on soil properties with time (according to fallow age). Invariably, this implied that

as fallows grow older in age, the more they accumulate organic matter. Thus, succession impacts the soil as more dead plants and other organisms die and give way to other plants. The processes of secondary succession and their resultant effects on soil characteristics in the Cross River Rainforest is lacking in the already existing literature. However, even the studies like that of Aweto (1981 a, b & C; Donfack et.al (1995), Swaine and Hall (1983) which appear to be closer to the area of study also lack information on the study area. Hence, with the current trend in the Cross River Rainforest loss, which plays host to a lot of endemic, charismatic and keystone species (flora and fauna), therefore, this paper becomes pertinent as it intends to characterize the effects of secondary succession on the soils of the area. Based on these, the study seeks to achieve the following objectives such as: to examine the soil physico-chemical properties at the surface and sub-surface levels across the succession phases; to evaluate the various changes that occurred across the succession phases and to determine the roles and contributions of secondary succession activities on soil nutrients restoration in the area.

However, considering the role of forest ecosystem on livelihood sustainability of the forests community dwellers, whose source of income and revenue is dependent on forest resources cannot be overlooked at this point in time. Therefore, as the rainforest ecosystem degradation is ongoing, due to indiscriminate utilization/exploitation pattern and processes, there is the need for the understanding of the forest fallow dynamics that could help in the amelioration of the observed problems and further facilitate forest regeneration and restoration, thus, the alleviation of poverty among forest community dwellers.

MATERIALS AND METHODS

Study Area

The study was carried out in Oban Group Forest in Akamkpa Local Government Area, Cross River State. Geographically, the area lies between longitude 8° 06'0 and 8° 50' E and latitude 5° 00' and 5° 57' N. The climate is characterized by a double maxima rainfall beginning in the month of March to August, then August to October, reaching its peak in the month of July and September. The annual rainfall is about 2000-3000mm with average temperature of about 27°C, while relative humidity is about 80%. The area is characterized by luxuriant evergreen forest vegetation with few patches of secondary forest which constitutes the fallows (Offiong & Iwara, 2012). Many trees grow to the height of 30m - 60m tall. A larger number of trees have large buttresses, smooth barks, columnar holes and thick woody climbers. Several species of birds, mammals,

reptiles and insects are found in the area. The terrain is undulating with flood plains around the Ikpan River.

Soil Sampling

The quadrat approach was employed to collect surface (0-15cm) and sub-surface (15-30cm) soil samples from plots of 400m² across five succession phases namely, forbs, young fallow, mature fallow, secondary climax and primary climax. In all of 50 soil samples were collected (10 soil samples of both surface and sub-surface for each succession phase). The rationale behind the fallow segmentation was to enable the researcher observe changes in soil properties over time. The forbs area was 2-years old; young fallow was 3-7years old; mature fallow was 8-15-years old; secondary climax was 16-25-years old, while the primary climax was >25-years old. Information on the fallow ages of the respective succession phases was obtained from the local farmers using participatory rural appraisal (PRA). The collected soil samples were analyzed in the laboratory for soil physical and chemical properties.

RESULTS

Physical Properties of Surface Soil in the Succession Phases

The physical properties of surface soil in the succession phases are presented in Table 1. The result showed that the mature fallow had the highest sand content with a value of 75.2% next to it was the forbs and secondary climax with values of 77.2% respectively. However, the young fallow almost fell within the same range as it had a value of 71.2%. The secondary climax had the lowest sand content of 69.2%. In the same vein, the young fallow had the highest silt content in the area with a value of 27.4%. The young fallow with a percentage value of 13.4% was next. On the other hand, mature fallow and primary climax had moderate silt content with values of 11.4% respectively, while the secondary climax had the lowest silt content with a value of 9.4%. Similarly, the clay content was high in the primary climax with a value of 19.4%; this was followed by the mature fallow and secondary climax with values of 13.4% respectively. The young fallow and the forbs had low clay contents of 10.4% and 9.4% respectively. The moisture content of soil varied across the succession phases with the secondary climax recording the highest value of 38.0% followed by the primary climax of 36.6% and then the mature fallow with 35.1%; the availability of moisture was slightly the same between the forbs and young fallow with values of 28.7% and 27.8% respectively. The porosity of the soils varied across the succession phases with high values recorded in young fallow and primary climax with values of 56.64 g/kg and 53.12 g/kg respectively, while low values were recorded in the forbs and secondary climax

with values of 51.03 g/kg and 51.17 g/kg respectively. The soil particle size composition of soil as shown in Table 1 shows that the soils of the succession phases are principally sandy with sand constituting more than 65% of the inorganic mineral fragment. The soil of the succession phases is classified as loamy-sand having been derived from granitic parent materials.

Table 1: Physical properties of surface soil in the succession phases

Soil properties	Succession phases				
	Forbs	Young fallow	Mature fallow	Secondary climax	Primary climax
Sand content (%)	77.2	71.2	75.2	77.2	69.2
Silt content (%)	13.4	27.4	11.4	9.4	11.4
Clay content (%)	9.4	13.4	13.4	13.4	19.4
Porosity (g/kg)	51.03	56.64	52.73	51.17	53.12
Moisture content (%)	28.7	27.8	35.1	38.0	36.6

Chemical Properties of Surface Soil in the Succession Phases

Table 2 gives information on the chemical properties of surface soil across the succession phases. It showed that the level of organic carbon (OC) was high in the primary climax with a value of 1.71%, followed by the mature fallow with a value of 1.76% and then the forbs (1.48%), while the lowest proportion of OC was observed in the young fallow with value of 1.26%. The high OC content in the primary climax was attributed to the high density of tree and biomass accumulation. The level of total nitrogen was high in the mature fallow and primary climax soils with values of 0.42% respectively, followed by the forbs (0.36%) and the secondary climax (0.35%), the lowest value of 0.31% was recorded in the young fallow. The level of exchangeable bases (Ca, Mg, Na and K) varied across soils of the succession phases. The level of exchangeable calcium (Ca) was in the forbs with a value of 5.00cmol/kg followed by the young fallow and mature fallow with values of 2.24cmol/kg respectively, while the lowest value of 1.42cmol/kg was recorded in the primary climax.

Furthermore, the level of exchangeable magnesium (Mg) and sodium (Na) were high in the secondary climax and young fallow with values of 0.70cmol/kg and 0.35cmol/kg respectively, followed closely by the mature fallow/primary climax and secondary climax with values of 0.63cmol/kg and 0.11cmol/kg respectively, while the lowest values were recorded in the young fallow and forbs with values of 0.33cmol/kg and 0.08cmol/kg respectively. For exchangeable potassium (K) and cation exchange capacity (CEC), the

mature fallow and forbs recorded the highest value 0.13cmol/kg and 6.33cmol/kg respectively followed by secondary climax with values of 0.09cmol/kg and 4.55cmol/kg respectively. The lowest values of K and CEC were recorded in the primary climax with values of 0.06cmol/kg and 3.40cmol/kg respectively. The level of available phosphorus (Av. P) and pH varied across the succession phases with the highest value of 10.28mg/kg and 5.1 in the young fallow and forbs respectively, followed by the forbs and young fallowed with values of 7.1cmol/kg and 4.5 respectively. The lowest level of these two soil properties were found in the primary climax and secondary climax with value of 1.31cmol/kg and 4.1 respectively. On the other hand, the concentration of electrical conductivity happened to be high in the secondary climax with value of 0.45 dsm⁻¹, followed by the forbs with a value of 0.43 dsm⁻¹ and then the mature fallow (0.42 dsm⁻¹) while the lowest conductivity level across the succession phases were obtained in the young fallow with value of 0.04 dsm⁻¹.

Table 2: Chemical properties of surface soil

Soil properties	Succession phases				
	Forbs	Young fallow	Mature fallow	Secondary climax	Primary climax
Organic carbon (%)	1.48	1.26	1.76	1.45	1.71
Total nitrogen (%)	0.36	0.31	0.42	0.35	0.42
Ca (cmol/kg)	5.00	2.24	2.24	2.05	1.42
Mg (cmol/kg)	0.37	0.33	0.63	0.70	0.63
Na (cmol/kg)	0.08	0.35	0.09	0.11	0.09
K (cmol/kg)	0.08	0.08	0.13	0.09	0.06
C.E.C. (cmol/kg)	6.33	4.00	3.89	4.55	3.40
Av. P (mg/kg)	7.31	101.28	2.13	1.48	1.31
pH	5.1	4.5	4.3	4.1	4.3
Electrical conductivity (dsm ⁻¹)	0.427	0.067	0.421	0.451	0.394

Physical Properties of Subsurface Soil in the Succession Phases

Information on the physical properties of sub-surface soil across the succession phases is depicted in Table 3. From the table, the level of sand was relatively similar across the forbs, young fallow, mature fallow and secondary climax with values of 77.2%, 75.2% and 73.2% respectively. The least concentration of sand was in the primary climax with a value of 67.2%. However, on individual consideration, the forbs had more concentration of sand (77.2%), followed by the mature fallow (75.2%), while the young fallow and secondary

climax had the lowest contents of 73.2% respectively. The concentration of silt was high in the primary climax with a value of 23.4% followed by the forbs, young fallow and mature fallow with values of 9.4% respectively, while the secondary climax had the lowest concentration of silt with a value of 7.4%. On the same note, clay content was the same with values of 19.4% respectively for the secondary climax and primary climax, but low in the mature fallow with a value of 15.4%. Also, the level of porosity was high in the forbs and young fallow with values of 58.59g/kg respectively followed by the primary climax with a value 56.25g/kg. The lowest porosity level was recorded in the secondary climax with a value of 53.12g/kg. The availability of moisture which is influenced by tree density, forest crown and tree/shrub heterogeneity was high in the mature fallow with a value of 37.0%, followed by the secondary climax with a value of 34.0%, and then the young fallow (31.8%). The least concentration of moisture was obtained in the forbs (23.9%).

Table 3: Physical properties of sub-surface soil in the succession phases

Soil properties	Succession phases				
	Forbs	Young fallow	Mature fallow	Secondary climax	Primary climax
Sand content (%)	77.2	73.2	75.2	73.2	67.2
Silt content (%)	9.4	9.4	9.4	7.4	23.4
Clay content (%)	13.4	17.4	15.4	19.4	19.4
Porosity (g/kg)	58.59	58.59	53.91	53.12	56.25
Moisture content (%)	23.9	31.8	37.0	34.8	30.5

Chemical Properties of Sub-Surface Soil in the Succession Phases

Similarly, the proportion of organic carbon (OC) was high in the primary climax with a value of 1.43%, while the lowest value of 0.71% was obtained in the young fallow. For total nitrogen (TN) and exchangeable calcium (Ca), the highest values of 0.35% and 3.56cmol/kg were obtained in the primary climax/mature fallow and forbs respectively, while the lowest values of 0.17% and 1.27cmol/kg were obtained in the young fallow and primary climax respectively. The forbs and young fallow had the highest concentrations of exchangeable magnesium (Mg) and sodium (Na) with values of 0.88cmol/kg and 0.36cmol/kg respectively, while the lowest values of 0.43cmol/kg and 0.08cmol/kg were obtained in the young fallow and mature fallow respectively. For exchangeable potassium (K) and cation exchange capacity (CEC), the highest and lowest values of 0.14cmol/kg and 5.68cmol/kg were obtained in the

forbs as well as the young fallow, secondary climax and primary climax with values of 0.05cmol/kg and 2.80cmol/kg respectively. The level of available phosphorous and pH varied across the succession phases with the young fallow and forbs having the highest values of 13.96 mg/kg and 4.8 respectively, followed by the forbs and young fallow with values of 6.53mg/kg and 4.6 respectively. The lowest level of Av. P and pH were obtained in the primary climax with value of 0.40mg/kg and 4.2 respectively. The level of electrical conductivity in the soil was relatively the same with slight increase in the forbs and decrease in the young fallow with values of 0.46dsm⁻¹ and 0.03dsm⁻¹ respectively.

Table 4: Chemical properties of sub-surface soil

Soil properties	Succession phases				
	Forbs	Young fallow	Mature fallow	Secondary climax	Primary climax
Organic carbon (%)	1.38	0.71	1.43	0.95	1.43
Total nitrogen (%)	0.32	0.17	0.35	0.22	0.35
Ca (cmol/kg)	3.56	1.91	2.25	1.33	1.27
Mg (cmol/kg)	0.88	0.43	0.67	0.53	0.58
Na (cmol/kg)	0.10	0.36	0.08	0.09	0.11
K (cmol/kg)	0.14	0.05	0.11	0.05	0.05
C.E.C. (cmol/kg)	5.68	3.75	3.91	2.80	3.61
Av. P (mg/kg)	6.53	13.96	1.39	0.52	0.40
pH	4.8	4.6	4.5	4.5	4.2
Electrical conductivity (dsm ⁻¹)	0.460	0.030	0.454	0.330	0.369

DISCUSSION

The result shows a substantial increase in the levels of organic carbon and total nitrogen in the top soil across the various succession phases mostly mature fallow and primary climax. The substantial increase in OC and TN contents is attributed to the increase in the density of trees/shrubs, dense crown cover and the higher amount of litter production which *in situ* decomposes to add nutrient to the soil. The density of trees/shrubs provides adequate protection to the soil thereby, preventing unproductive loss of soil nutrient to soil erosion. The dense crown cover helps to attenuate the direct impact of raindrop on the soil, thereby keeping litter stable for decomposition. This observation confirmed the findings of Aweto (1981) that a substantial increase in total nitrogen and organic matter occurred in the upper part (10cm) of soil profiles during the first ten years of fallow. In the same vein, available phosphorous in the

fallow cycles was high in the surface soils across the succession phases. This trend is affirmed by earlier studies carried out by Chidimayo and Kiribisa, (2003), and Aweto, (1981). However, the contents of available phosphorus and cation exchange capacity are high in the forbs and young fallow, the levels of these soil nutrients decrease substantially in the secondary and primary climaxes. The decrease in the level of Av. P and CEC in the latter stage of the succession stage is attributed to nutrient immobilization as well as the high intake of nutrient by the trees. The high proportion of Av. P in forbs and young fallow is attributed to the abundance of herbaceous vegetation which helps to decrease the leaching of basic cation (Ekukinam et al., 2014). Also, the high Av. P content may be attributed to the pH of the forbs and young fallow soil which favour phosphorus increase.

CONCLUSION

The physico-chemical properties of soil across the succession phases in the study area indicated a significant variation in their composition respectively. Invariably, the soils in the primary and secondary climaxes appeared to be richer in nutrients than others. This was attributed to the relatively low level of disturbances and lengthens fallow periods. However, this is consequent upon the presence of tree/shrub species with a high level of healthy tree growth variables and litter cover/content. Invariably, the rich soils of the area ensure the longevity of the forest ecosystem and its resources which gives both tangible and intangible values to the inhabitants of the area. Consequently, it is recommended that the rainforest fallow areas should be put under the gazette of protected areas. This is because, forest fallows mark the beginning of succession which over time restores the degraded forest that once existed in the area before disturbance though with slight modification.

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